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EFFECT OF GIBBERELLIN ON SEEDED VITIS VINIFERA, AND ITS TRANSLOCATION WITHIN THE VINE[1,2]

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INTRODUCTION

GIBBERELLIN loosens clusters of compact-clustered grape varieties when they are sprayed at bloom or prebloom stages (Weaver, 1958*a, b;* Weaver and McCune, 1959*b*).[5] The loosening resulting from prebloom sprays is caused both by elongation of cluster parts and by formation of shot berries. The loosening at bloom, believed to be mainly the result of retarded development of many ovaries and berries, is primarily a thinning effect with little lengthening of cluster parts. Gibberellin has hastened flowering, coloration, and maturation in certain grapes (Weaver and McCune, 1959*b*). However, the crop level may have been lower in gibberellin-treated plots, thus accounting for the more rapid maturation.

The present experiments were conducted in 1958 in an attempt to answer certain questions raised by work done in 1957 (Weaver and McCune, 1959*b*). One problem was to determine the proper concentration of compound and time of treatment to produce loose clusters with a minimum of shot berries. In most experiments, crop weights were obtained so that effect of cropping on coloration and ripening could be separated from effects produced by gibberellin.

Other experiments concerned with translocation of gibberellin within the vine included study of: the translocation occurring from young treated shoots and within older shoots; the effect of age of leaf on absorption; and the influence, on fruit, of gibberellin absorbed by leaves.

MATERIALS AND METHODS

Mature Zinfandel, Carignane, Ribier, and Red Malaga vines in an irrigated vineyard at the University of California at Davis were used. Zinfandel and Carignane, both wine grapes, were head-trained and spur-pruned; Ribier and Red Malaga, table grapes, were trained to bilateral cordons and spur-

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[5] See "Literature Cited" for citations referred to in the text by author and date.

TABLE 1

LENGTH OF ZINFANDEL CLUSTERS AFTER TREATMENT AT VARIOUS STAGES OF DEVELOPMENT WITH GIBBERELLIN AT 100 PPM

(Figures are averages of 10 replicate clusters.)

Date of treatment	Date of measurements							Length at harvest, 9/12
	4/16	4/23	4/30	5/7	5/14	5/21	5/29	
	inches	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*
Not dipped	1.1	2.4	3.5	4.8	5.7	6.7	7.2	7.5
4/16/58	1.2	5.9	11.2	13.0	13.1	12.9	12.4	12.9
4/16 4/30 5/14	1.0	4.7	9.5	14.3	14.4	14.7	14.0	14.0
4/23	...	2.2	5.7	11.2	11.5	11.8	11.3	12.0
4/23 5/7	...	2.6	6.3	11.6	12.5	11.5	12.4	10.3
4/30	...	...	3.3	8.3	10.5	10.6	10.6	10.9
4/30 5/14 5/21	...	...	3.5	8.0	10.1	10.0	9.9	9.9
5/7	...	...	...	4.3	7.5	8.5	8.4	8.1
5/14	...	...	...	...	5.4	7.5	7.4	7.2
5/21	...	...	...	...	...	8.3	9.8	10.3
5/29	...	...	...	...	...	...	7.9	8.8

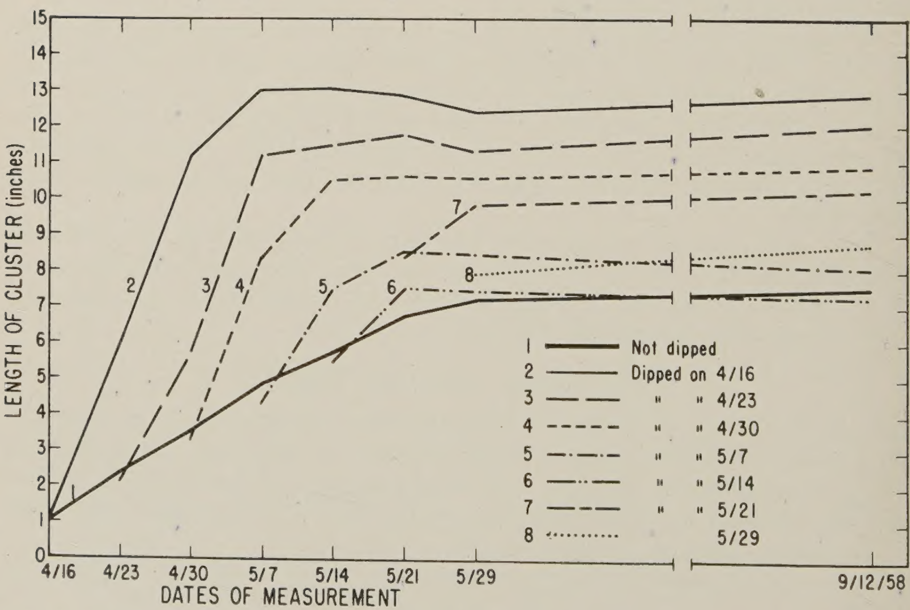

Fig. 1. Elongation of clusters of Zinfandel grapes after being dipped in gibberellin at 100 ppm on various dates.

pruned. In all spray experiments, unless otherwise indicated, both the clusters and the foliage were heavily sprayed. Three-gallon, 1-quart, and De Vilbiss No. 15 atomizer sprayers were used. The water-soluble potassium salt of a gibberellic acid containing 80 per cent active ingredient was furnished by Merck and Company. All concentrations are expressed on a parts per million (ppm) basis, and Dreft was always used as a wetting agent unless otherwise stated.

Length of cluster was measured from base of peduncle to apex of rachis. The berries at the apex were not included in the length, so that any increase in cluster length could not be attributed to the enlarging berry.

In determining the number of berries per cluster, all berries were counted except those that remained small, hard, and green. Berries that had softened and colored were counted even though they were seedless and much smaller than the normal size. To determine the degree to which a cluster had been loosened, the total volume of a cluster containing no berries was estimated, on the basis that the controls had zero per cent unoccupied space. This estimate is referred to as the "looseness" percentage. A low percentage (3 to 20) would mean that the cluster has been loosened to a desirable degree. Larger percentages might result in too great a crop loss because clusters would be too straggly.

Average weight of berries was determined by weighing 100 or 200 in duplicate. A Balling hydrometer was used to find percentage of total soluble solids in the juice. Total acidity was determined by diluting 10 ml of juice to 50 ml with distilled water, and titrating with 0.113 N/NaOH, using phenolphthalein as an indicator. Results are expressed as gm of tartaric acid per 100 ml of juice.

EXPERIMENTAL

Loosening of Clusters and Rate of Maturation

The relation of stage of vine development to applications of gibberellin was studied, and an attempt was also made to find out whether gibberellin hastens ripening.

Dipping Experiments with Zinfandel. The purpose was to study response to gibberellin of Zinfandel clusters at various developmental stages. On April 16, when the clusters were only about 1⅛ inches long, 10 clusters were dipped in gibberellin at a concentration of 100 ppm. Other series of clusters were dipped on later dates (table 1). One series of clusters was dipped on April 16, April 30, and May 14; another was first treated on April 23 and re-treated on May 7; and one was first treated on April 30 and re-treated on May 14 and May 21. The treatment dates with length of cluster of controls are shown in table 1. On May 21 about half the calyptras had fallen, and by May 29 shatter had occurred.

By April 23, many clusters treated on April 16 were extending beyond the growing tip of the shoot. On May 14, clusters treated on April 16 or April 23 showed much crinkling and curling, and on May 21 all clusters treated on or before May 7 showed much bending and had long pedicels. The treatment on May 14 produced much less elongation than did previous treat-

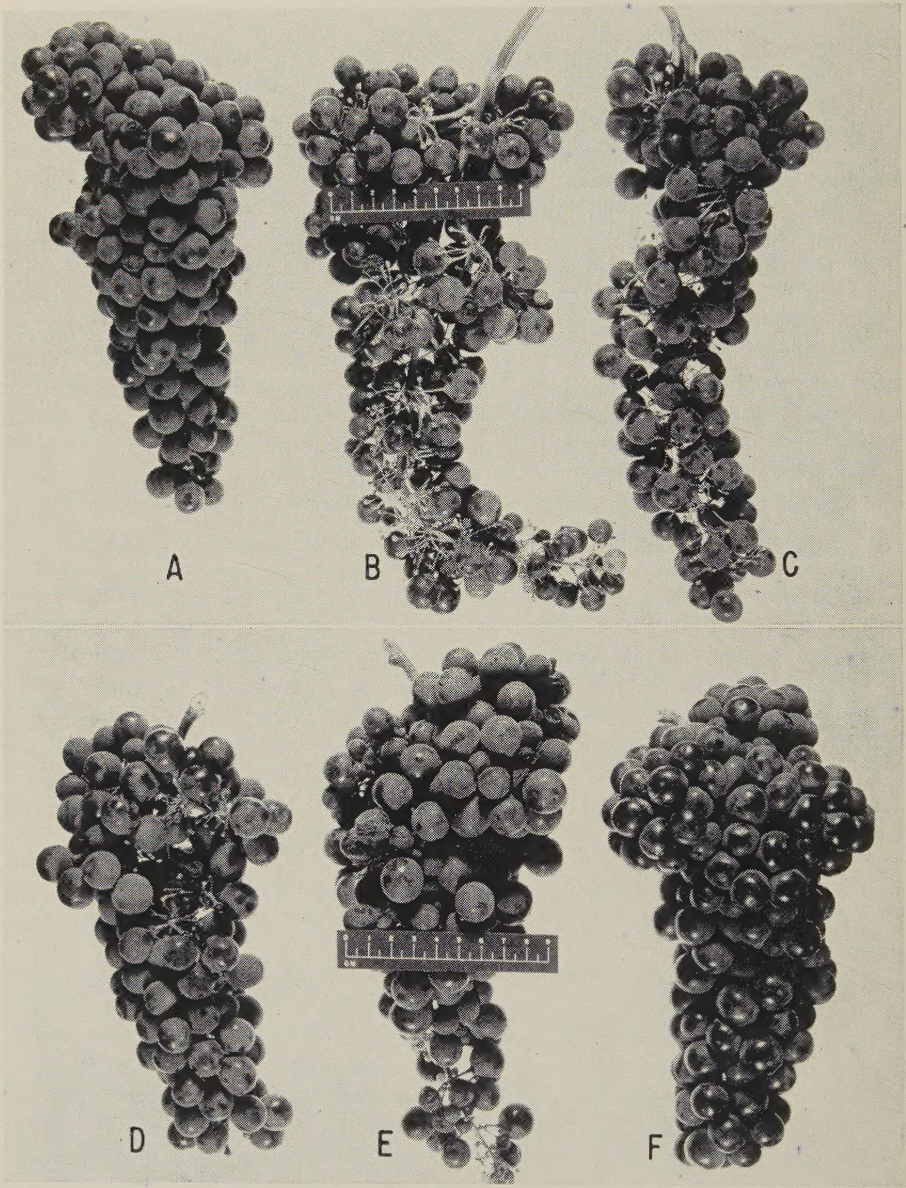

Fig. 2. Clusters of Zinfandel at harvest (September 12) after being dipped in gibberellin at 100 ppm on the following dates: *B,* April 16; *C,* April 30; *D,* May 14; *E,* May 21; *F,* May 29. *A* is undipped control. Note that progressively more shot berries and elongation usually occur as a result of the earlier treatments. Note splitting of the peduncle at the earliest dipping (*B*). (Photographed September 12, 1958.)

ments (fig. 1), and final length was probably not different from controls.

Control clusters regularly elongated until May 29 when almost maximum length was attained (table 1, fig. 1). Clusters dipped on April 16 rapidly increased in length until maximum length was reached on May 7. At harvest on September 12, clusters treated on April 16 were almost twice as long as the controls. Clusters dipped on April 23, April 30, May 7, May 14, or May 21 responded similarly to those dipped on April 16, but at progressively lower rates. Little or no increase in length resulted from dipping clusters on May 29. The apparent decrease in length of clusters as a result of any treatment

TABLE 2

DATA AT HARVEST FOR ZINFANDEL CLUSTERS DIPPED, AT VARIOUS DEVELOPMENTAL STAGES, IN GIBBERELLIN AT 100 PPM

(Figures are averages of 10 replicate clusters.)

Date of treatment	Length of peduncle	Length of second lateral from base	Length of pedicel
	cm	*cm*	*mm*
Not dipped	1.12	4.19	8.4
4/16/58	3.08	5.28	15.0
4/23	1.87	5.05	14.9
4/30	1.40	5.15	14.5
5/7	1.90	3.75	11.2
5/14	1.80	3.20	8.4
5/21	1.22	5.00	9.3
5/29	1.28	4.95	9.5
L.S.D. at 5 per cent	0.74	1.18	1.1

may be accounted for by crinkling of clusters. Variation between the initial lengths of clusters dipped on May 21 or May 29 and those of the controls attests to the increasing variability in clusters as they grow larger on the vine. However, the significant point is the slope of these curves as compared with those of the controls. The data clearly show that the earlier a cluster is treated, the greater is its response.

When clusters first treated on April 16 were redipped on April 30, they showed an increase in length, but a third dipping on May 14 had little additional effect (table 1). Clusters first dipped on April 23 and redipped on May 7 showed a slight additional increase in length. Clusters first dipped on April 30 and redipped on May 14 and May 21 showed no noticeable additional lengthening. Thus redipping clusters after May 14 had little or no additional effect on elongation.

Clusters were harvested on September 12 (table 2, fig. 2). About half of the compact control clusters had developed rot. Clusters dipped on April 16 or April 23 had a looseness percentage of about 65, and some rachises were callused. Clusters dipped on April 30, May 7, May 14, and May 21 had looseness percentages of 70, 50, 10, and 10, respectively, and large, thickened pedicels. Clusters dipped on May 29 were like the controls.

Clusters dipped on April 16, April 30, and May 14 had a looseness percentage of about 85, with many split rachises and long, thickened pedicels.

Those dipped on April 23 and May 7 had a looseness percentage of about 70.

Gibberellin at 100 ppm obviously forms far too many shot berries for application at that rate to be of practical use. Nevertheless, data were taken at harvest to show amount of elongation of cluster parts, because similar effects, to a lesser degree, could be expected as a result of lower concentrations of gibberellin. The data (table 2) show that length of peduncle was usually increased by gibberellin, especially as a result of the first treatment. However, no significant increases resulted from treatments on April 30, May 14, May 21, or May 29. Length of second lateral from base was usually increased by gibberellin, although not significantly, and pedicel length was significantly increased by the dippings on April 16 through May 7, inclusive.

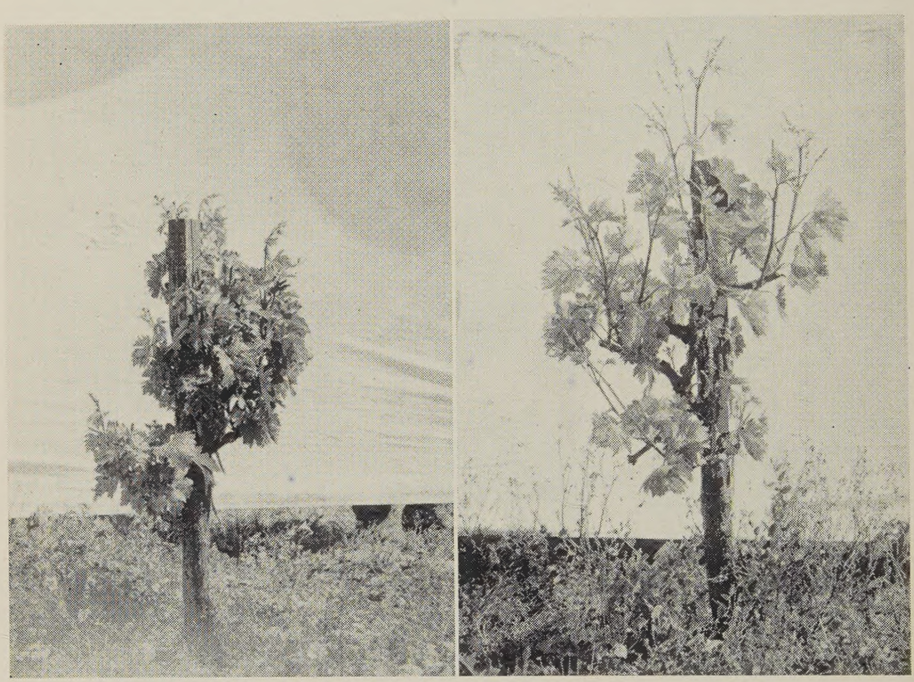

Fig. 3. Right: Zinfandel vine nine days after being sprayed with gibberellin at 50 ppm. Left: unsprayed control. Note elongated shoots and clusters and paler foliage on sprayed vine. (Photographed April 24, 1958.)

Spraying Zinfandel Vines at Prebloom or Bloom Stages. The purpose was to spray entire vines at different stages of development, and note effects on looseness of cluster and on rate of ripening. On April 15, the date of the first treatment, shoots were 1½ to 3 inches long, and clusters were just appearing—some were ¼-inch long. Vines were sprayed with gibberellin at 0, 10, 25, or 50 ppm, five vines per treatment. A second series of vines was sprayed on April 28 when the shoots were 7 to 13 inches long, and clusters 1½ to 3 inches. There was a growth of 6 to 9 inches on many shoots, with some also showing less than 6 inches and a few showing more than 9. On May 9, when a third series of vines was sprayed, many shoots were 22 to 26 inches

long, and clusters averaged about 5 inches long. A final series of vines was sprayed on May 19 when about 50 per cent of the calyptras had fallen. A split-plot experimental design was used.

On April 28, foliage sprayed on April 15 at 10 ppm was still slightly yellowish (fig. 3), and the intensity of yellow increased with higher concentrations, a phenomenon previously noted (Weaver and McCune, 1959*b*). This yellowing also occurred with the later treatments.

TABLE 3

FLOWERING IN ZINFANDEL GRAPES SPRAYED ON VARIOUS DATES WITH GIBBERELLIN AT VARIOUS CONCENTRATIONS

(Observations made on May 19, 1958.)

Date of treatment	Concentration of gibberellin	Calyptras fallen
	ppm	*per cent*
April 15	0	0
	10	75
	25	80
	50	85
April 28	0	30
	10	75
	25	85
	50	90
May 9	0	50
	10	75
	25	75
	50	85

Data in table 3 show that flowering was hastened by the first three sprayings, despite the irregularity in the controls. All spraying also markedly increased coloration (table 4).

The data at harvest (table 5, figs. 4, 5, 6, 7) show that the first treatment was the least toxic of the four sprayings as judged by the looseness percentage. The treatment at bloom (May 19) resulted in many shot berries which increased the looseness. Many control clusters were rotting, but there was little rotting among the sprayed clusters.

Weight of crop was usually decreased by gibberellin except as a result of the spraying on April 28. The degree Balling was usually increased by gibberellin, a fact which may be partly explained on the basis of a lighter crop. In the spraying on April 28, however, ripening was definitely hastened by gibberellin, since cropping levels of sprayed vines were about equal to those of the controls. Percentage of total acid was usually inverse to degree Balling.

Spraying Zinfandel at Postbloom Stages. Immediately following bloom on May 28, Zinfandel vines were sprayed with gibberellin at 0, 1, 5, 25, and 50 ppm, four vines per treatment. A second series of vines was similarly sprayed on June 9 after the shatter of berries following bloom, when the berries were 5 to 6 mm in diameter.

The percentages of total surface of fruit colored for vines sprayed on May 28 at 0, 1, 5, 25, or 50 ppm were 0, 0, 1, 5, and 20, respectively, when observed

on July 21. The percentages in the same order for vines sprayed on June 9 were 0, 0, 1, 3, and 10, respectively. Fruit was harvested on September 8. The data (table 6) show much rot in all treatments as a result of both dates of spraying although it was much reduced in clusters sprayed at 50 ppm.

Gibberellin at 25 and 50 ppm, applied on May 28, and at 50 ppm, applied on June 9, resulted in looseness percentages varying from 20 to 50 (table 6,

TABLE 4

EFFECT OF GIBBERELLIN SPRAYS APPLIED AT VARIOUS TIMES ON COLORATION OF ZINFANDEL GRAPES

(Figures are approximate percentages of total fruit surface colored.)

Concentration of gibberellin	Date of spraying			
	April 15	April 28	May 9	May 19
ppm	Observations made on July 11			
0	0	0	0	0
10	0	1	10	5
25	0	2	20	10
50	2	30	30	15
	Observations made on July 21			
0	1	1	2	1
10	1	5	25	15
25	2	15	40	20
50	5	50	70	50
	Observations made on July 31			
0	10	10	10	10
10	20	60	60	25
25	20	65	65	30
50	40	75	85	75

fig. 8). (No estimate of looseness was made on clusters sprayed on June 9 with compound at 25 ppm.) There was much variation in crop weight per vine. The indication was that the compound at 5 or 25 ppm, applied on June 9, increased the percentage of total soluble solids. The crop weights of these treatments and of the control were about the same, and could therefore be eliminated as a factor influencing the rate of maturation.

Spraying Carignane Vines. Carignane was sprayed at each of six developmental stages. The first treatment was made on April 15 when average length of shoots was about 2½ inches, and of clusters, about ⅜ inch. Gibberellin was applied at 0, 10, 25, or 50 ppm, five vines per treatment, for the first four treatments, and at 0, 1, 5, 25, or 50 ppm for the last two treatments, four vines per treatment. The second series of vines was treated on April 28 when many shoots were 14 to 18 inches long, with the larger clusters 3½ to 4 inches long. At the third treatment on May 9, many shoots were 24 to 27 inches long,

and the clusters, 5 inches. A fourth series was sprayed on May 19 when about 2 per cent of the calyptras had fallen, and a fifth on May 28 when almost all the calyptras had fallen. The final series was treated on June 9 after the shatter of impotent berries following bloom. A split-plot experimental design was used.

TABLE 5

DATA AT HARVEST (SEPTEMBER 8) FOR ZINFANDEL GRAPES SPRAYED WITH GIBBERELLIN ON VARIOUS DATES

(Figures are averages of five replicate vines.)

Treatment, concentration of gibberellin	Estimate of looseness	Number of clusters with rot per vine	Weight of crop per vine	Degrees Balling	Total acid, per cent tartaric
	Sprayed April 15				
ppm	*per cent*		*lbs*		
0	0	8.0	48.7	13.0	0.91
10	5	0.6	45.8	13.3	0.78
25	30	0.4	39.3	15.6	0.80
50	35–40	0.0	25.5	18.1	0.69
	Sprayed April 28				
0	0	10.8	33.7	14.6	0.85
10	10	1.6	38.9	15.6	0.77
25	25	1.2	37.0	16.4	0.86
50	50	1.4	30.2	19.8	0.66
	Sprayed May 9				
0	0	9.2	44.6	14.6	0.83
10	25	0.4	31.6	19.6	0.69
25	30	2.4	34.2	18.6	0.72
50	60	0.8	24.3	21.6	0.60
	Sprayed May 19				
0	0	10.0	36.9	14.8	0.82
10	20–25	0.0	31.5	18.7	0.74
25	30–40	2.4	31.2	19.9	0.76
50	50	0.0	22.6	21.3	0.64
(1)*	..	....	12.1	0.7	0.03
(2)†	..	....	4.3	0.6	0.05

* L.S.D. at 5 per cent for concentrations on a given date of spraying.
† L.S.D. at 5 per cent for different spraying dates at a given concentration.

Observations on May 19 showed that flowering was markedly hastened, especially by the first two treatments (table 7). Observations on July 31 showed that coloration was slightly advanced by many treatments (table 8).

At harvest there was little or no rotting in the control or in any spray treatment. Many sprayed clusters were tough and wiry, especially those sprayed with gibberellin at 25 or 50 ppm.

As with Zinfandel, the estimate of looseness was least in the earliest of the prebloom treatments (made from April 15 to May 19, inclusive). Weight of

TABLE 6

DATA AT HARVEST (SEPTEMBER 8) FOR ZINFANDEL GRAPES SPRAYED WITH GIBBERELLIN ON MAY 28 OR JUNE 9
(Figures are averages of four replicate vines.)

Treatment, concentration of gibberellin	Number of clusters with rot per vine	Estimate of looseness	Weight of crop per vine	Degrees Balling	Total acid, per cent tartaric
	Sprayed May 28				
ppm		*per cent*	*lbs*		
0	9.5	0	23.6	17.5	0.76
1	9.8	0	37.8	14.7	1.01
5	10.0	0	35.0	16.3	0.93
25	13.0	20–25	37.6	16.8	0.89
50	7.0	40	24.6	18.3	0.75
	Sprayed June 9				
0	15.0	0	28.3	14.3	1.18
1	10.8	0	19.8	15.6	1.05
5	18.0	0	26.1	16.4	0.98
25	16.5	..	32.9	16.4	0.78
50	4.3	45–50	14.9	19.9	0.62
(1)*	5.0	..	8.1	0.9	0.08
(2)†	N.S.	..	3.8	0.8	0.09

* L.S.D. at 5 per cent for concentrations on a given date of spraying.
† L.S.D. at 5 per cent for different spraying dates at a given concentration.

TABLE 7

FLOWERING IN CARIGNANE GRAPES SPRAYED ON VARIOUS DATES WITH GIBBERELLIN AT VARIOUS CONCENTRATIONS
(Observations made on May 19.)

Date of treatment	Concentration of gibberellin	Calyptras fallen
	ppm	*per cent*
April 15	0	5
	10	10
	25	50
	50	50
April 28	0	10
	10	20
	25	40
	50	50
May 9	0	2
	10	5
	25	5–10
	50	5–10

crop per vine was usually decreased by gibberellin, although at 10 ppm the reduction was often little or none (table 9). This can usually be accounted for largely by decrease in number of berries per cluster. Since crop weights were quite variable, it was difficult to ascertain the effect of gibberellin on rate of maturation. However, the application at 10 ppm on May 9 may have hastened maturation.

Fig. 4. Zinfandel grape clusters at harvest, from vines sprayed on April 15 with gibberellin at the following concentrations: *A*, unsprayed; *B*, 10 ppm; *C*, 25 ppm; *D*, 50 ppm. The concentrations of 25 (*C*) and 50 ppm (*D*) resulted in elongated clusters and pedicels, and many shot berries. (Photographed September 8, 1958.)

TRANSLOCATION OF GIBBERELLIN

Observations in 1957 indicated that, when gibberellin was applied to young shoots of a vine, the compound was not translocated to adjacent shoots, as judged by stimulation of growth (Weaver and McCune, 1959*b*). The experiments described below sought to confirm these data more fully. Experiments were also performed on older shoots. Other studies were made on influence of age of leaf on absorption of gibberellin and, finally, on influence of foliage as an avenue of entry of gibberellin into the clusters.

Translocation in Young Shoots. In one experiment, Ribier vines with shoots usually 7 to 9 inches long and clusters 1½ to 3 inches long were used. Four shoots (including their clusters) on each of three vines were placed in waterproof, plastic bags, and the whole vine was then sprayed with gibber-

Fig. 5. Zinfandel grape clusters at harvest, from vines sprayed on April 28 with gibberellin at the following concentrations: *A*, unsprayed; *B*, 10 ppm; *C*, 25 ppm; *D*, 50 ppm. This treatment resulted in more injury than did that of April 15 (fig. 4). (Photographed September 8, 1958.)

TABLE 8

EFFECT OF GIBBERELLIN SPRAYS APPLIED AT VARIOUS TIMES ON COLORATION OF ZINFANDEL GRAPES

(Figures are approximate percentages of total fruit surface colored on July 31.)

Concentration of gibberellin	Date of spraying					
	April 15	April 28	May 9	May 19	May 28	June 9
ppm						
0	5	5–10	5	1	5	3–4
1	..	..	..	..	5	5
5	..	..	..	..	10	10
10	10	20	5	5	..	..
25	15	10	10	5	10	10
50	5	5	5	10	5	10

ellin at 100 ppm, on April 28. After the spray had dried, the bags were removed. Four shoots on each of three other unsprayed vines were also tagged for subsequent measurement. Sprayed and unsprayed shoots and clusters on sprayed vines, and shoots and clusters on unsprayed vines were measured at subsequent intervals. Data obtained on May 15 are shown in table 10. Although sprayed shoots and clusters were greatly stimulated, unsprayed shoots on sprayed vines grew similarly to those on control vines, indicating

TABLE 9

DATA AT HARVEST (SEPTEMBER 25) FOR CARIGNANE GRAPES SPRAYED WITH GIBBERELLIN ON VARIOUS DATES

(Five vines per replicate at the first four sprayings, four at the last two)

Treatment, concentration of gibberellin	Estimate of looseness	Weight of crop per vine (lbs)	Number of berries per cluster*	Degrees Balling	Total acid, per cent tartaric
	Sprayed April 15				
ppm	*per cent*				
0	0	56.1	.....	19.1	0.96
10	5	53.0	.....	18.6	0.88
25	15	49.1	171.8	19.3	0.72
50	35	43.0	.....	20.7	0.74
	Sprayed April 28				
0	0	61.0	209.1	18.1	0.78
10	15	52.4	154.9	19.3	0.70
25	20	51.8	136.7	19.7	0.78
50	45	52.5	146.5	19.3	0.86
	Sprayed May 9				
0	0	46.0	.....	18.9	0.79
10	15	49.3	.....	20.0	0.93
25	40–45	35.6	118.4	20.9	0.68
50	60	29.7	.....	23.5	0.74
	Sprayed May 19				
0	0	49.5	.....	18.2	0.90
10	25	39.5	.....	19.5	0.79
25	50	37.6	96.6	20.5	0.80
50	60–70	24.2	.....	23.2	0.59
	Sprayed May 28				
0	0	47.5	.....	17.3	0.87
1	1	44.8	.....	18.8	0.81
5	3	43.9	.....	18.1	0.76
25	3	36.5	142.2	20.9	0.78
50	30	41.9	.....	19.4	0.84
	Sprayed June 9				
0	0	60.9	.....	17.2	0.98
1	0	57.1	.....	17.5	0.92
5	0	54.1	.....	17.7	0.83
25	0	52.4	184.7	17.0	0.77
50	0	49.5	.....	18.1	0.86
(1)†	..	5.5	.....	0.5	0.05
(2)‡	..	4.3	.....	0.8	N.S.
(3)§	..	N.S.	.....	N.S.	0.05
(4)‖	..	4.6	.....	0.6	0.04

* Averages of 40 or 50 clusters (10 replicate clusters from each vine).
† L.S.D. at 5 per cent for concentrations at a given date of spraying (April 15–May 19, inclusive).
‡ L.S.D. at 5 per cent for different spraying dates at a given concentration (April 15–May 19, inclusive).
§ L.S.D. at 5 per cent for concentrations at a given date of spraying (May 28 or June 9).
‖ L.S.D. at 5 per cent for different spraying dates at a given concentration (May 28 or June 9).

Fig. 6. Zinfandel grape clusters at harvest, from vines sprayed on May 9 with gibberellin at the following concentrations: *A*, unsprayed; *B*, 10 ppm; *C*, 25 ppm; *D*, 50 ppm. This treatment resulted in less elongation of clusters than did that of April 28 (fig. 5), and in many shot berries. (Photographed September 8, 1958.)

Fig. 7. Zinfandel grape clusters at harvest, from vines sprayed on May 19 with gibberellin at the following concentrations: *A*, unsprayed; *B*, 10 ppm; *C*, 25 ppm; *D*, 50 ppm. Little or no elongation of cluster occurred with this treatment, but there were many large shot berries. (Photographed September 8, 1958.)

that there was little or no translocation from one young shoot to another, at least not in sufficient amounts to result in measurable changes of growth.

In a second experiment carried on in the same block of Ribier vines, one cordon of each of three vines was sprayed with gibberellin at 100 ppm on April 28. On each vine, four shoots on the sprayed cordon and four on the unsprayed were tagged for subsequent measurement. Four shoots were also tagged on each of three unsprayed vines for controls. The results (table 11) show no evidence of any translocation from one cordon to another.

Fig. 8. Zinfandel clusters at harvest after being sprayed with gibberellin at 50 ppm on May 28, 1958 (*B*). *A*, unsprayed controls. Note loosening of sprayed clusters as a result of formation of shot berries. (Photographed September 8, 1958.)

In another experiment, Carignane vines with shoots about 6 inches long were used. Spurs bearing two uniform shoots were selected. On 12 spurs, the apical shoot was sprayed, on April 22, with gibberellin at 100 ppm, by means of a De Vilbiss No. 15 atomizer sprayer. The basal shoots were enclosed in waterproof, plastic bags during spraying. A paper towel was placed around the shoot during spraying to prevent drift. After the spray dried, the bags were removed. The basal shoots of 12 other spurs were similarly sprayed while the apical shoot was protected from the spray. The shoots of 12 unsprayed spurs were used for controls—six apical and six basal. Shoot and cluster lengths were measured at subsequent intervals. The data (table 12) indicate that there was no translocation of gibberellin from apical to basal or basal to apical shoots. Data for cluster elongation gave similar results, but they are not presented.

Translocation in Older Shoots. The purpose was to determine the degree to which older shoots respond to gibberellin, and how much of the total foliage on a shoot must be sprayed in order to obtain maximum stimulation

TABLE 10

EFFECT OF GIBBERELLIN AT 100 PPM, APPLIED ON APRIL 28, ON LENGTH GROWTH OF YOUNG RIBIER GRAPE SHOOTS AND CLUSTERS

(Measurements made on May 15; figures are averages of 12 replicates.)

Treatment	Growth of shoots	Growth of clusters
	inches	*inches*
Sprayed shoots	39.0	12.3
Unsprayed shoots on sprayed vines	33.8	7.0
Shoots on unsprayed vines	33.5	6.9
L.S.D. at 5 per cent	3.5	1.2

TABLE 11

TRANSLOCATION OF GIBBERELLIN IN A RIBIER GRAPEVINE, AS INDICATED BY LENGTH GROWTH OF SHOOTS AND CLUSTERS

(Compound at 100 ppm sprayed on April 28, on one cordon of vine; measurements made on May 15; figures are averages of 12 replicates.)

Treatment	Length growth	
	Shoots	Clusters
	inches	*inches*
Sprayed cordon of sprayed vine	40.2	12.1
Unsprayed cordon of sprayed vine	27.6	6.1
Unsprayed vine	32.9	7.1
L.S.D. at 5 per cent	3.6	1.7

TABLE 12

LENGTH GROWTH OF YOUNG CARIGNANE GRAPE SHOOTS AFTER SPRAYING WITH GIBBERELLIN AT 100 PPM ON APRIL 22

(Measurements made on June 17; figures are averages of 12 replicates.)

Spur treatment	Length
	inches
Apical shoot sprayed:	
Apical shoot	102.0
Basal shoot	74.8
Basal shoot sprayed:	
Apical shoot	74.9
Basal shoot	88.5
Shoots not sprayed	78.4

of growth. Red Malaga vines with shoots about 3 feet long were used. A pin was placed through the stem 2 inches from the apex, as a marker from which to measure new growth (Weaver and McCune, 1959*a*). On June 23, four series of 10 shoots each were sprayed with gibberellin at 100 ppm, as follows: 1) the apical 6 inches; 2) the apical third; 3) the apical two thirds; 4) the entire shoot.

On July 1, new growth was measured by recording the length from the pin to the apexes and subtracting 2 inches (Weaver and McCune, 1959*a*). The average lengths of new growth were: control shoots, 3.3 inches; shoots with upper 6 inches sprayed, 9.4 inches; upper one third, 9.6 inches; upper two thirds, 10.2 inches; entire shoots sprayed, 10.4 inches. Spraying the apical 6 inches resulted in just as much elongation as did spraying the whole shoot. However, this situation might not prevail if lower concentrations were used.

TABLE 13

NEW GROWTH OF SHOOTS AFTER SPRAYING APICAL OR BASAL SHOOTS OF CARIGNANE GRAPE SPURS WITH GIBBERELLIN AT 100 PPM ON JULY 1

(Measurements made on July 11; figures are averages of 10 replicates.)

Spray treatment	Apical shoot	Basal shoot
	inches	*inches*
Control (unsprayed)	2.78	1.64
Apical shoot sprayed, basal not sprayed	5.71	2.14
Apical shoot not sprayed, basal shoot sprayed	1.17	4.25
L.S.D. at 5 per cent	1.96	2.24

In a second experiment, Carignane vines with shoots 58 to 68 inches long were used. The vines appeared to be at the end of their vegetative growth. Two spurs per vine were selected, each bearing two shoots. On July 1, the apical shoot on each of 10 spurs was sprayed with gibberellin at 100 ppm, and the basal shoots of 10 other spurs were similarly sprayed. To confine the spray to the intended shoot, the sprayed shoots were enclosed in a waterproof, plastic bag 38 inches in circumference and 58 inches long. The lower end was fastened with paper clips during spraying. The bag was removed several minutes after spraying, and care was taken not to wet adjacent shoots. Pins were put through the stems 2 inches from the apex, as markers from which to measure new growth. The new growth (table 13), measured 10 days after treatment, showed little translocation from one shoot to another.

Influence of Age of Leaf on Absorption and Translocation. On April 22 the basal leaf on each of 12 shoots of Carignane (about 6 inches long) was painted with gibberellin at 100 ppm, and in a second series, the youngest leaf with a width of ½ inch or more was painted. The purpose was to determine which treatment resulted in most rapid shoot elongation. One series of shoots served as controls. Measurements of shoots and clusters were made at subsequent intervals. The data showed that more gibberellin reached the growing shoot apex by way of the basal leaf. For example, on June 17 the average lengths of control shoots, shoots with apical leaf treated, and shoots

with basal leaf treated were 75.1 (7.5), 83.8 (6.7), and 91.9 (8.5) inches, respectively. Average cluster lengths are shown in parentheses. The L.S.D. at 5 per cent was 6.6 for shoot length and 1.0 for cluster length.

Influence on Fruit of Gibberellin Absorbed by Leaves. The purpose was to determine whether gibberellin enters fruit through the leaves. Zinfandel vines selected had an average shoot length of 16 to 17 inches, and cluster length of around 3 inches. Two vines were sprayed, on April 29, with gibberellin at 50 ppm, and in addition the clusters were dipped. On two other vines, clusters were dipped but foliage was not sprayed. The clusters on two other vines were enclosed in waterproof, plastic bags, and the foliage was then sprayed. After drying, the bags were removed. Two other vines served as the unsprayed controls. At maturity, all treated vines had greatly elongated clusters, although dipping in addition to spraying resulted in a higher percentage of shot berries than did other gibberellin treatments. On October 6, the average lengths of cluster (10 replicates) were: leaves not sprayed, clusters not dipped, 6.3 inches; leaves sprayed, clusters bagged, 7.9; leaves not sprayed, clusters dipped, 6.8; and leaves sprayed, clusters dipped, 7.9. The L.S.D. at the 5 per cent level was 1.1. These figures indicate that much gibberellin enters fruit through the leaves.

DISCUSSION

The earlier Zinfandel clusters were dipped in gibberellin, the greater was their response as measured by cluster elongation. Thus, it is the younger tissues that are most responsive to the compound. By flowering time, the response was practically nil. The increase in size of clusters as a result of flower cluster thinning has also been shown to be less effective the longer the treatment is delayed (Winkler, 1931).

That the earliest spray treatments in Zinfandel and Carignane resulted in less response than did a later one may be explained by the fact that, in very young shoots, the stream of elaborated food materials is moving mainly into the leaves and not out of them. It is likely that gibberellin moves with the stream of elaborated food materials, as do other plant-regulators (Weaver and DeRose, 1946). The same line of reasoning may be used to explain why treatment of older leaves on young shoots resulted in greater shoot elongation than when younger leaves were treated. Further experiments should be performed in which equal amounts of gibberellin are applied to leaves of various ages.

The primary purpose of prebloom sprays on compact clustered varieties is to loosen the cluster and thus eliminate or reduce bunch rot. In countries where Bordeaux sprays are utilized to combat the downy mildew (*Plasmopara viticola*), a loose cluster would be favorable for penetration of the fungicide into the cluster. The loosening attained is a resulting combination of elongation of cluster parts and development of shot berries. The results of this paper indicate there is a period of several weeks during which gibberellin may be applied in order to loosen the clusters. Spraying of very young shoots (6 to 8 inches) should be avoided because, as the basal internodes become elongated, it may be difficult to maintain the shape of the vine. Spray-

ing at bloom is too late for much elongation of cluster parts, but a "thinning" action occurs at that time as a result of shot berry development. It may be just as difficult to select the proper concentration of gibberellin for use at full bloom as it is to determine that of other thinning agents (Weaver, 1954). Postbloom sprays often have little effect in loosening the clusters, but perhaps do affect the rate of maturation.

A period of around two to three weeks before the inception of bloom would be a suitable time for application of prebloom sprays in California. The proper concentration to use must be selected for each variety and each climatic region. A suitable concentration may range from 2 to 10 ppm. The effect of gibberellin on vine growth the year following spraying must be studied, and the effect of applications over a period of years must be determined, in order to indicate whether stimulation of vegetative growth will result in a weakening of the vine.

Crop was often reduced by applications of gibberellin. However, too high concentrations for practical use were usually applied in these experiments. Since, in many instances, a decrease in amount of rotting could be expected, the amount of sound fruit might be equal to or greater than that of unsprayed vines. Furthermore, more or longer spurs could be left on gibberellin-treated vines to replace any loss in crop as a result of treatment.

Prebloom sprays of gibberellin hastened flowering and coloration in Zinfandel and Carignane. However, in too many instances in these tests the cropping levels varied so much from those of unsprayed vines that this could not often be eliminated as a factor affecting ripening. Cropping levels have been shown to have a marked influence on coloration and maturation in wine grapes (Weaver, Amerine, and Winkler, 1957).

An urgent problem still is to demonstrate conclusively the effect of gibberellin on maturation. Experiments performed with Thompson Seedless failed to reveal hastening of maturation. However, there are probably varietal differences in response. Gibberellin sprays may increase the total amount of foliage, and this could result in faster maturation. Another factor might be the wider distribution of leaves resulting from internode elongation, which gives the foliage a more favorable light exposure.

Several experiments showed little or no translocation of gibberellin from one shoot to another, at least not in sufficient amounts to result in measurable changes in shoot growth. However, there was considerable movement within a shoot. In these experiments, gibberellin readily entered fruit of Zinfandel by way of the leaves. In other experiments with Black Corinth and Thompson Seedless, however, the foliage was found to be a relatively ineffective avenue of entry to the fruit (Weaver and McCune, 1959*c*). This may be partially accounted for by the fact that gibberellin was applied at 50 ppm to the Zinfandel, but at only 25 ppm to the Black Corinth and Thompson Seedless. Also, Zinfandel was treated at an earlier stage of development. Here again, varietal differences may affect translocation.

Elongating the peduncle with gibberellin could possibly be of value in mechanical harvesting of grapes. A long peduncle would enable the cutter bar of the mechanical grape harvester now under development to remove practically all the fruit (Winkler, Lamouria, and Abernathy, 1957). Un-

fortunately, the peduncle is the most mature part of the cluster, and hence responds least to gibberellin. Shoots must be treated at a young stage in order to elongate the peduncle, and often too many shot berries occur with such early treatments. This problem requires further study.

SUMMARY

1. Zinfandel clusters at various prebloom stages dipped in gibberellin at 100 ppm demonstrated that the earlier the cluster is treated the greater is its elongation. Redipping clusters after May 14 had little or no additional effect on elongation of clusters previously treated.

2. Zinfandel vines at prebloom or bloom stages were sprayed with gibberellin at 1 to 50 ppm. The earliest spray, applied to very young shoots, was least toxic as judged by degree of loosening of clusters. Treatment at bloom resulted in many shot berries. Flowering and coloration of fruit were hastened by most treatments, and the spraying on April 28 appeared to result in a higher percentage of total soluble solids. Two postbloom sprays on Zinfandel also resulted in loosening of clusters following development of shot berries, and there was an indication that ripening was hastened by the compound applied at 5 or 25 ppm on June 9. Rot occurred much less frequently in sprayed clusters. Level of crop was often reduced by the sprays as a result of development of shot berries.

3. Carignane vines at each of six stages of development were sprayed with gibberellin at 1 to 50 ppm. The earliest treatment gave the least response among the prebloom applications. Weight of crop was usually depressed by gibberellin because of a decrease in number of berries in sprayed clusters.

4. Gibberellin was not translocated from one shoot to another when judged by its effect on shoot elongation. In Red Malaga shoots about 3 feet long, the spraying of the apical 6 inches with gibberellin at 100 ppm resulted in just as much elongation as did spraying the whole shoot.

5. More gibberellin reached the growing shoot apex of young Carignane shoots about 6 inches long when the basal leaf was treated than when an apical leaf was treated.

6. An experiment in which foliage and/or clusters of Zinfandel were treated with gibberellin showed that much cluster elongation and shot berry development resulted when compound was absorbed by the leaves.

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